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A non-native carnivore living in a cultural landscape

Activity patterns, space use and feeding habits of American mink (*Neovison vison*) in a fishpond area in Northern Germany – potential impact and derived management recommendations

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Table of Contents

1 Summary

Alongside the destruction of habitat, the impact of invasive alien species (IAS) is considered as one of the most important threats to global biodiversity. Therefore, international directives as well as national legislation call for measures to prevent the further spread of already established IAS as well as to limit their negative effects on native flora and fauna. This study deals with one of these non-native species – the American mink (*Neovison vison*). In order to get information about ecology and behaviour of this semiaquatic carnivore, a small population in a north German fishpond area, where mink has been spreading since the 1970s, was investigated. During the years 2003 to 2006 data about annual and circadian activity patterns, space use, territorial system as well as feeding habits and their variations during different seasons were collected. For this purpose, altogether 14 individuals (nine males, five females) were monitored using radio-telemetry. Based on the results, the potential impact of American mink on indigenous species was discussed and implications for mink control and management were deduced.

American mink are difficult to radio tag. The small difference between their head and neck circumferences mean that the radio collars must be worn tightly to prevent loss. A methodological evaluation of conventional collar transmitters revealed that in six out of eight cases serious skin injuries on the necks were the consequences. Therefore, all radio collars were removed and radio transmitters were surgically implanted in the peritoneal cavity of mink by veterinarians. One male bit open the sutures and died after emergency surgery, but in 13 cases implantation did not affect survival or reproduction of the mink. With reference to animal welfare, intraperitoneal implantation of radio transmitters (in combination with observation and quarantine for several days after operation) instead of external radio collars were recommended for long term telemetry studies of American mink.

Analyses of annual activity patterns revealed significant differences in seasonal activity rates. Both sexes reduced their average activity rates in cold winter months (October to February) to about 23 %. This energy-saving strategy is possible because of sufficient food availability, especially of fish, at this time. In March, male as well as female mink considerably increased their activity to almost 40 % due to the mating season. In summer months, during the pup-raising period (May to August), female activity continued to be high (between 40 and 50 %).

However, male mink which are not involved in rearing the young, were less active (about 30 %) until July. But in August and September, the time of juvenile dispersal followed by changes in the territorial system and intraspecific aggression, activity rates of males increased again up to 43 %.

Circadian activity rhythms differed markedly between sexes. All investigated females exhibited a perennial diurnal pattern. Three of five investigated male mink showed typical nocturnal activity throughout the year. Two males displayed arrhythmic behaviour; they did not prefer any time of the day for activity. On the one hand, gender differences in annual as well as circadian activity patterns of American mink reflect the diversity in ecological constraints, primarily the investment into reproduction. On the other hand, the different temporal strategies of sexes may have the potential to reduce intraspecific, especially intersexual competition.

Investigating territorial systems and space use of mink, in comparison to other European studies, relatively large home ranges combined with a quite low population density were observed. In summer months male mink used on average 15.4 km length of waterway and female mink used on average 9.3 km length of waterway. In accordance with the trend of activity rates, male and female mink reduced their large summer home ranges by more than half during the cold winter period. But all-season male mink used significantly larger areas than female mink. High intersexual overlapping rates of home ranges and low levels of intrasexual overlapping of neighbouring home ranges confirm intrasexual territoriality of American mink. Probably, the low population density (0.6-0.7 individuals/km^2) allows such high variations in seasonal and sexual home range size. During the mating season males considerably enlarged their home ranges and roamed nearly through the entire study area in search of receptive females. The shifting of stable temporary home ranges observed within one season or between the same seasons of consecutive years demonstrates the highly dynamic nature of spatial behaviour among American mink. The recorded characteristic features of spatial and temporal behaviour should be considered when planning monitoring- and management measures of this invasive carnivore. For instance, the reduced home ranges and activity rates during winter months should be taken into account in mink trapping projects.

Analyses of more than 2500 scatsamples of radio tracked mink show that investigated animals principally prey on fish, small mammals and birds (eggs inclusive). There were significant seasonal variations of diet composition. In spring, the three categories of prey - fish, mammals and birds (eggs inclusive) - were hunted in similar amounts. During summer, birds and their eggs made up the main part of the diet followed by mammals. In autumn, the proportion of birds in the mink diet decreased, whereas fish gained in importance. This trend continued during the winter period, when mink preyed almost exclusively on fish. Throughout the entire year amphibians, crustaceans, insects, molluscs and reptiles were found only occasionally in scatsamples. Among birds, the mink preyed mainly on the Eurasian Coot (*Fulica atra*) followed by the Mallard (*Anas platyrhynchos*). Mammalian prey was clearly dominated by the water vole (*Arvicola terrestris*) and among fish, mink hunted especially perch (*Perca fluviatilis*), roach (*Rutilus rutilus*) and carp (*Cyprinus carpio*). Results clearly demonstrate that mink is an opportunistic predator, which hunts its prey according to availability and vulnerability, respectively. Despite the high portions of fish in the autumn and winter diet, the economic damage to fishery caused by mink seems to be low. Perch and roach were preyed on in higher frequencies than the carp which is economically relevant. However, high predation on birds and their eggs during the breeding season indicates a potential negative impact of mink on waterfowl.

To summarise, it can be noted that characteristic features of the anthropogenically influenced study area affect feeding habits, activity patterns, space use and density of local mink population. In this regard the management of fishponds, which influences seasonal availability of habitat- and food resources for mink, plays an important role.

American mink is regarded as “invasive”, because a negative impact on native species has been proved by several European studies. Consequently, this study recommends management with a focus on effective monitoring and, if necessary, control or exclusion measures adapted to the specific local requirements. Furthermore, to prevent additional introductions into the wild, the still existing farms have to be protected against outbreaks and liberations. In the long term, a general ban on the trade and keeping of American mink would be desirable.

2 Zusammenfassung

Der Einfluss invasiver, gebietsfremder Arten wird neben der Habitatzerstörung als eine der größten Gefährdungen der Biodiversität weltweit angesehen. Sowohl internationale Umweltvereinbarungen als auch die nationale Gesetzgebung fordern daher Maßnahmen, die eine weitere Ausbreitung bereits etablierter invasiver Neozoen verhindern und deren negative Einflüsse minimieren. Die vorliegende Studie befasst sich mit einer dieser Neozoen - dem Amerikanischen Nerz bzw. Mink (*Neovison vison*). Um Erkenntnisse zu Ökologie und Verhalten des semiaquatischen Musteliden in Deutschland zu gewinnen, wurden Daten zu tages- und jahreszeitlichen Aktivitätsmustern, zu Raumnutzung und Territorialsystem sowie zur Nahrungswahl und den jahreszeitlichen Unterschieden im Beutespektrum der Art erhoben. Dafür konnten in den Jahren 2003 bis 2006 in einem Fischteich-Gebiet in Mecklenburg-Vorpommern, wo sich Minke bereits seit den 1970er Jahren etabliert haben, insgesamt 14 Individuen (neun Männchen, fünf Weibchen) radiotelemetrisch überwacht werden. Anhand der Ergebnisse wird einerseits der potentielle Einfluss des gebietsfremden Raubsäugers auf einheimische Arten abgeschätzt und diskutiert. Andererseits werden die Ergebnisse herangezogen, um effektive Monitoring- und Managementmaßnahmen abzuleiten.

Eine methodische Evaluation von Halsbandsendern zeigte, dass in sechs von acht Fällen die getesteten Halsbänder, die aufgrund des sehr ähnlichen Hals-Kopf-Umfanges der Individuen relativ eng angelegt werden müssen, Hautverletzungen verursachten. Infolgedessen wurden die Halsbandsender gegen durch Tierärzte operativ in die Bauchhöhle eingesetzte Implantationssender ausgetauscht. Auch bei allen nachfolgend gefangenen Tieren wurden die Sender implantiert. Bei insgesamt 14 durchgeführten Erstimplantationen beeinflussten mit Ausnahme eines Falles (Tod durch Aufbeißen der Naht) die Implantate weder das Überleben, noch die Reproduktion der Minke. Daher ist v.a. in Hinblick auf Tierschutzaspekte die Senderimplantation (in Kombination mit einer Mehrtages-Quarantäne) anstatt der Verwendung von externen Halsbandsendern zu empfehlen.

Die Analyse der circannuellen Aktivitätsmuster ergab signifikante Unterschiede der saisonalen Aktivitätsraten. Während der kalten Wintermonate (Oktober bis Februar) zeigten beide Geschlechter mit durchschnittlich etwa 23 % eine vergleichsweise geringe Aktivität. Diese

energiesparende Verhaltensweise war möglich, da auch im Winter ein ausreichend hohes Nahrungsangebot, vor allem an Fisch, vorhanden war. Im März kam es sowohl bei den Männchen als auch bei den Weibchen zu einem durch die Paarungszeit verursachten, beträchtlichen Anstieg der mittleren Aktivitätsraten auf fast 40 %. In den Sommermonaten (Mai bis August) waren die weiblichen Tiere, durch die Anforderungen der Jungenaufzucht bedingt, anhaltend häufig aktiv (zwischen 40 und 50 %). Die Aktivitätsraten der nicht an der Jungenaufzucht beteiligten Männchen dagegen nahmen im April wieder ab, um bis zum Juli auf einem vergleichsweise geringen Niveau von etwa 30 % zu bleiben. Sie stiegen jedoch während der Monate August und September erneut auf etwa 43 % an. Zu dieser Zeit wandern gewöhnlich die Jungtiere ab und suchen sich ein eigenes Streifgebiet (= Aktionsraum), dadurch kommt es zu Änderungen im Territorialsystem und damit einhergehenden innerartlichen Auseinandersetzungen.

Beide Geschlechter unterscheiden sich stark in ihren tageszeitlichen Aktivitätsrhythmen. Alle Weibchen waren ganzjährig tagaktiv. Von den fünf untersuchten Männchen zeigten drei typische Nachtaktivität im gesamten Jahresverlauf. Die beiden anderen männlichen Tiere verhielten sich in ihren Aktivitätsrhythmen indifferent, sie zeigten das ganze Jahr über keine Präferenzen für eine bestimmte Tageszeit. Die geschlechtsspezifischen Unterschiede sowohl in den circannuellen als auch in den circadianen Aktivitätsmustern spiegeln zum einen die verschiedenen Anforderungen an die Geschlechter wieder, vor allem die Investitionen in die Fortpflanzung. Zum anderen können die geschlechtsspezifisch unterschiedlichen Zeitnutzungs-Strategien zu einer Minimierung der innerartlichen, vorzugsweise der intersexuellen Konkurrenz führen.

Die Analyse der Telemetriedaten hinsichtlich Raumnutzung und Territorialsystem ergab im Vergleich zu anderen europäischen Studien relativ große individuelle Aktionsräume verbunden mit einer geringen Populationsdichte im Untersuchungsgebiet. So erstreckten sich die durchschnittlich genutzten Sommerstreifgebiete der Männchen auf 15,4 km und die der Weibchen auf 9,3 km Flusslauf bzw. Teichufer. Entsprechend dem Trend der saisonalen Aktivitätsmuster, reduzierten beide Geschlechter ihre großen Sommerstreifgebiete während der Winterhalbjahre um mehr als die Hälfte der Fläche. Allerdings nutzten die Männchen zu allen Jahreszeiten wesentlich größere Aktionsräume als die weiblichen Minke. Große Streifgebietsüberlappungen zwischen den Geschlechtern sowie verhältnismäßig niedrige

Überlappungsraten der benachbarten Streifgebiete von Tieren des gleichen Geschlechts bestätigen die intrasexuelle Territorialität der Art. Die erheblichen Unterschiede der saisonalen und geschlechtsspezifischen Aktionsraumgrößen werden vermutlich durch die ermittelte, vergleichsweise geringe Populationsdichte (0,6-0,7 Individuen/km^2) ermöglicht. Die ausgedehnte und sich fast über das gesamte Untersuchungsgebiet erstreckende Raumnutzung der Männchen während der Paarungszeit ist durch die Suche nach fortpflanzungsbereiten Weibchen bedingt. Die Raumnutzung der untersuchten Minke unterliegt einer hohen Dynamik, dies wird durch die häufige räumliche Verschiebung temporär stabiler Streifgebiete innerhalb einer Jahreszeit oder auch zwischen den gleichen Jahreszeiten aufeinanderfolgender Jahre verdeutlicht. All diese ermittelten charakteristischen Besonderheiten im Raum-Zeit-Verhalten der Art sollten bei der Entwicklung von Monitoring- und Managementkonzepten berücksichtigt werden. So müssen beispielsweise bei der Fallenjagd im Winter die zu dieser Zeit stark verkleinerten Streifgebiete und die reduzierten Aktivitätsraten Beachtung finden.

Die Analyse der über 2500 Losungsproben telemetrierter Minke zeigte, dass sich die untersuchten Tiere hauptsächlich von Fisch, Kleinsäugern und Vögeln (inklusive deren Eiern) ernährten. Dabei traten allerdings signifikante saisonale Unterschiede in der Nahrungszusammensetzung auf. So wurden im Frühjahr die drei Beutekategorien Fisch, Kleinsäuger sowie Vögel und deren Eier in ähnlichen Anteilen erbeutet. Während des Sommers bildeten Vögel und Vogeleier die Hauptbeute, gefolgt von Kleinsäugern. Im Herbst verringerte sich der Vogel- und Kleinsäugeranteil im Beutespektrum zugunsten von Fisch. Dieser Trend setzte sich bis in den Winter fort; in dieser Jahreszeit ernährten sich die Minke fast ausschließlich von Fisch. Amphibien, Reptilien, Krebstiere, Insekten und Mollusken wurden im gesamten Jahresverlauf nur gelegentlich gefressen. Innerhalb der Gruppe der Vögel prädierten die Minke vor allem Blässhühner (*Fulica atra*), gefolgt von Stockenten (*Anas platyrhynchos*). Das Kleinsäuger-Beutespektrum wurde eindeutig von der Schermaus (*Arvicola terrestris*) dominiert und unter den Fischen erbeuteten die Minke vorzugsweise Flussbarsche (*Perca fluviatilis*), Plötzen (*Rutilus rutilus*) und Karpfen (*Cyprinus carpio*). Die Ergebnisse der Nahrungsanalyse bestätigen den Mink als einen opportunistischen Prädator, der seine Beutetiere je nach Verfügbarkeit bzw. dem erforderlichen Jagdaufwand nutzt. Trotz des hohen Fischanteils in der Herbst- und Winternahrung ist der durch den Mink verursachte

ökonomische Schaden schätzungsweise relativ gering. Flussbarsch und Plötze wurden in höheren Frequenzanteilen erbeutet als der wirtschaftlich relevante Karpfen. Die starke Prädation von Wasservögeln und deren Eiern besonders in den Frühjahrs- und Sommermonaten weist allerdings auf einen potentiell negativen Einfluss des invasiven Raubsäugers auf diese Tiergruppe hin.

Zusammenfassend lässt sich festhalten, dass die spezifischen Charakteristika des anthropogen geprägten Untersuchungsgebietes sowohl Nahrungsökologie und Aktivitätsmuster als auch Raumnutzung und Populationsdichte der lokalen Minkpopulation beeinflussen. Eine besondere Rolle hierbei spielt die Bewirtschaftung der Fischteiche, denn vor allem daraus resultiert für die Minke eine saisonal unterschiedliche Verfügbarkeit an Lebensraum und Nahrung.

Negative Auswirkungen des Amerikanischen Nerzes auf die einheimische Tierwelt wurden in anderen europäischen Ländern belegt und rechtfertigen die Einstufung dieser Art als „invasiv“. Demzufolge wird in der vorliegenden Arbeit ein Management empfohlen, bei dem der Focus auf einem effektiven Monitoring und gegebenenfalls auf zweckmäßigen, an die lokalen Bedingungen angepassten Fang- oder Abwehrmaßnahmen liegt. Zudem sollten, um einer weiteren Ausbringung in das Freiland vorzubeugen, die wenigen noch existierenden Minkfarmen besser gegen Ausbrüche bzw. Freilassungsaktionen gesichert werden. Langfristig ist ein generelles Besitz- und Vermarktungsverbot für die Art wünschenswert.

3 General Introduction

Dispersal of organisms is a natural process and one of the drivers of evolution on earth, but historically this process has been limited by biogeographical barriers. However, humans, as well as many accompanying animal species, have gradually overcome these barriers. There is therefore a long history of species introduction to Europe. Alien (synonymous with exotic, non-native) species are organisms introduced outside their natural past or present distribution range and outside of their natural dispersal potential. They have been introduced by human agency, intentional or unintentional, either directly or indirectly (Pyšek et al. 2009). The main process of globalisation and biological invasions began in 1492 with the discovery of America (Nentwig 2007). Therefore, especially in the German-speaking area archaeozoans, which were introduced before the discovery of America, were distinguished from neozoans, which were introduced after 1492 (Pyšek et al. 2009). Those alien species which cause significant harm to biological diversity, ecosystem functioning, socio-economy or human health, are considered as invasive (CBD 2002; Pyšek et al. 2009). Hence it is important to distinguish between alien species - which in many cases are harmless - and invasive alien species (IAS). The latter nowadays were considered as one of the most important direct drivers of biodiversity loss and ecosystem service changes worldwide (Clout and Williams 2009; European Environment Agency 2012). The impact of IAS on biodiversity can occur at gene, species and ecosystem levels (European Environment Agency 2012). Invasive animals can affect native species directly by predation, competition, hybridisation and introduction of pathogens / parasites, or indirectly by degrading their habitat (Baillie et al. 2004). The introduction of vertebrate predators, for example, has been the primary cause of extinction globally, especially on islands (Blackburn et al. 2004).

In recent decades the rates of new introductions as well as the recorded impacts have accelerated. Today over 11.000 alien species are estimated to be present in Europe, 5-30 % of them (depending on taxonomic group) are known to have a negative ecological impact and additional 13 % are noted to have a negative economical impact (Drake 2009; Vilà et al. 2010). However, some introduced species have not been able to establish self-sustaining populations and have failed to become naturalised. Besides, in a few cases exotic species could be intentionally eradicated, such as the coypu (*Myocastor coypus*) and the muskrat (*Ondatra*

zibethicus) in Great Britain (Genovesi 2005). Accordingly, nowadays 21 of the 71 noted non-European alien mammals are reported as extinct. The others are considered either as "established", as "present but not established" or as "unknown". These species account for 22 % of the total number of mammals present in Europe, and 55 % of the alien mammals are known to cause ecological impacts (Genovesi et al. 2012).

Germany is one of the most invaded countries in Europe, nine exotic mammal species are actually established (Genovesi et al. 2009). Among which the three exotic carnivores - American mink (*Neovison vison*), raccoon dog (*Nyctereutes procyonoides*) and raccoon (*Procyon lotor*) are listed in the 100 of the worst IAS (Vilà et al. 2009). Moreover, American mink is considered as one of the four most invasive mammals in Europe (Nentwig et al. 2010). Regarding the numbers of affected species, the American mink is the alien mammal with the highest impact, because it is reported to affect 47 native species, including six threatened species (Genovesi et al. 2012). In several parts of Europe this small carnivore has become a serious problem because of its impact on prey species as well as on competitors (Bonesi and Palazon 2007; Macdonald and Harrington 2003).

Living in freshwater and marine habitats, the semi-aquatic mustelid hunts terrestrial as well as aquatic prey according to their availability (Dunstone 1993; Jędrzejewska et al. 2001). Intrasexual territoriality as the basic mustelid spacing patterns also seems to apply to the mink, but in some studies evidence for territoriality is weak (Dunstone 1993; Larivière 2003; Powell 1979). There is a distinct sexual dimorphism in size and body mass, with females about 50 % lighter in mass (Larivière 2003). Mating takes place from February to April, after a variable gestation period on average six young are born between April and May. They disperse in August and both sexes become fertile in their first year (Bonesi 2009; Dunstone 1993).

Originally mink occurred in almost all parts of North America from Alaska and Canada through the United States except Arizona and the dry parts of California, Nevada, Utah, New Mexico, and Western Texas (Larivière 2003). The semi-aquatic mustelid was introduced due to fur farming in Europe and Asia starting in the 1920s. Deliberate releases of breeding stock into the wild (e.g. in the former Soviet Union during 1930-1950) or escapes from fur farms and additional "liberations" by animal rights activists during the last decades led to the spread of this species and its naturalisation in the wild (Dunstone 1993; European Environment Agency 2012). Consequently, American mink is now widespread in many parts of Europe and Asia.

Even in South America feral populations have been reported (Previtali 1998; Schüttler et al. 2008). Since the first evidence of wild mink in 1950s, this carnivore rapidly spread through aquatic habitats in Northern and Eastern parts of Germany supported by repeated farm outbreaks (Mitchell-Jones et al. 1999; Stubbe 1993).

Although in recent years many projects have been funded by the European Commission, the knowledge about long-term effects of biological invasions is still limited (European Environment Agency 2012). Therefore, the European Commission has made a commitment that 'By 2020, Invasive Alien Species (IAS) and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS' (European Union 2011). Furthermore, the German Federal Nature Conservation Act (Bundesnaturschutzgesetz § 40, 3) prescribes that measures have to be taken to prevent the further spread of already established invasive species as well as to limit the negative effects of this spread.

It is essential to gain knowledge about basic ecological parameters, such as activity patterns, territorial system and space use as well as the feeding habits of American mink in Germany, where only few investigations regarding distribution and behaviour of this exotic species have been conducted so far. This knowledge will help us to understand the mechanisms that are influencing native fauna, particularly animals of high conservation or economic relevance, and to identify reasonable and economically viable management strategies.

Therefore, a research-project on exotic carnivores in an anthropogenically modified fishpond area in Northern Germany was conducted. Within the scope of this project I examined different ecological parameters of mink. In detail, the following questions were investigated:

Methodological study:

Radio-tagging

1) Is the implantation of intraperitoneal transmitters an advisable alternative to radio-collars for radio tagging American mink?

Ecological studies:

Activity patterns

2) Are there variations of activity rates within the course of the year and if so, are these differences in circannual activity patterns the same between sexes?
3) Is the circadian activity pattern of mink influenced by sex or season?

Space use

4) Do home range sizes in an artificial fishpond area differ from that in natural habitats?
5) Do mink show the typical spacing pattern of intrasexual territoriality and is there an influence of sex or season on home range size?
6) How stable is the spatial organisation of the mink population?

Feeding habits

7) Are there seasonal or sexual differences in the composition of mink diet?
8) Which are the most commonly used prey species of mink?

Finally, it is hypothesised that special characteristics of the human-influenced study area have an effect on feeding habits, activity patterns, space use and density of local mink population. This seems to be caused especially by the management of fish ponds and the resulting seasonal differences in availability of habitat as well as prey.
Based on the results, conclusions regarding potential negative ecological or economic impact of American mink as well as prevention and management options were deduced.

4 Study Area and Methods

The present investigation was conducted in a lowland area known as “Lewitz”, located about 20 km southeast of the city of Schwerin, Mecklenburg-Western Pomerania. This cultural landscape is characterised by forests, meadows, pastures, wooded inland dunes scattered along the meandering River “Alte Elde” and large fish ponds, which cover a region of almost 10 km^2. The “Lewitz” area is protected as a Ramsar Site and a European Bird Reserve with Special Protection Area legislation (Zimmermann 2002). The fish ponds, especially stocked with carp (*Cyprinus carpio*), are a nature reserve with seasonal changes in water level. In winter, most of them are completely drained off and the remaining fish (except carp) are concentrated in ice-free ditches, canals and water-filled fish-harvesting pools. The younger carp spend the winter in small hibernating ponds (Wichmann 2002). Furthermore, the area is an important breeding as well as resting and wintering ground for waterfowl such as ducks, rails, grebes, geese and swans (Zimmermann 2008). Reed belts (Phragmitetum) characterise the eutrophic ponds, with willows (*Salix sp.*), birches (*Betula pendula*) and poplars (*Populus sp.*) lining the riverbanks and lake edges (Möller 2002). Together with surrounding artificial canals and numerous drainage ditches, these fish ponds make up the study area. A lot of small mammals, especially water voles (*Arvicola terrestris*), occupy the waterside habitats. In addition to American mink, the area is inhabited by two other species of exotic carnivores – raccoon and raccoon dog and eight native carnivores amongst others European otter (*Lutra lutra*) and polecat (*Mustela putorius*) (Binner 2002). The climate is relatively mild and humid. The average annual precipitation was 625 mm, and the average annual temperature was 8.4 °C (Zimmermann 2008).

This study is based on data which were collected from October 2003 to April 2006. Within that period 14 mink (nine males and five females) were radio-tracked for different tracking periods. After the decision against radio collars was made, intraperitoneal implanted transmitters (Wagener-Telemetrysystems, Köln, Germany and Biotrack Ltd., Wareham, Dorset, UK) were used for tagging. A portable ®TRX-1000S receiver (Wildlife Materials Inc., Illinois) connected to an H-antenna (HB9CV) was used for monitoring. Animals were searched for by car and then precisely located on foot using triangulation and homing (Kenward 2001). Recorded telemetry data (4,283 radio locations) were analysed using ArcView Gis 3.3 (Environmental Systems

Research Institute, Inc., USA) and Ranges 6 v1.201 (Anatrack Ltd.) in order to get information about space use and activity patterns of investigated animals.

To study the diet of invasive American mink, 2502 scat samples (991 from females and 1511 from males) were collected between October 2003 and October 2005. Through radio-tracking it was possible to assign each scat sample to a specific individual and date, because I searched for latrines immediately after the radio-tracked mink rested there. After identification of prey remains, a classification according to nine different food categories based on taxonomic groups was made. In order to analyse the seasonal feeding habits of investigated mink, the "percentage frequency of occurrence" as well as the "percentage of food biomass consumed" of these prey groups were calculated.

5 Radio tagging American mink (*Mustela vison*) – experience with collar- and intraperitoneal implanted transmitters

Zschille, J.; Stier, N.; Roth, M. (2008): Radio tagging American mink (Mustela vison) experience with collar- and intraperitoneal implanted transmitters. European Journal of Wildlife Research 54: 263-268. DOI 10.1007/s10344-007-0139-6

6 Gender differences in activity patterns of American mink *Neovison vison* in Germany

Zschille, J; Stier, N.; Roth, M. (2010): Gender differences in activity patterns of American mink Neovison vison in Germany. European Journal of Wildlife Research 56: 187-194. DOI 10.1007/s10344-009-0303-2

7 Dynamics in space use of American mink (*Neovison vison*) in a fishpond area in Northern Germany

Zschille, J; Stier, N.; Roth, M.; Berger, U. (2012): Dynamics in space use of American mink (Neovison vison) in a fishpond-area in Northern Germany. European Journal of Wildlife Research 58: 955-968. DOI 10.1007/s10344-012-0638-y

8 Feeding habits of invasive American mink (*Neovison vison*) in northern Germany—potential implications for fishery and waterfowl

Zschille, J.; Stier, N.; Roth, M.; Mayer, R. (2014): Feeding habits of invasive American mink (Neovison vison) in northern Germany—potential implications for fishery and waterfowl. Acta Theriologica 59: 25-34. DOI 10.1007/s13364-012-0126-5

9 Concluding Discussion

9.1 Activity patterns, Space use and Feeding habits as well as the potential ecological and economic Impact

Feeding habits, activity patterns and space use of American mink are closely related with each other and all these forms of behaviour are influenced by parameters of the mink habitat. This long-term-study allows us to analyse the interaction of these ecological parameters during the course of the year, taking into account the special dynamic characteristics of the human-modified study area. Factors such as availability of food and potential den sites, population density or stability of the social system, as well as individual demands (e.g. during reproduction) can vary between different seasons. It is therefore expected that home range size, activity patterns and diet composition will also change over the annual cycle.

The artificial fishponds in the study area deliver an adequate supply of food, even in winter. In this season both sexes reduced their large summer home ranges to relatively small areas and minimized territorial behaviour. Because mink preyed almost exclusively on fish at this time, they were able to restrict their activities to hunting at prey hot spots, such as ice-free ditches, canals, water-filled fish-harvesting pools and hibernating ponds (Wichmann 2002). This reduction of home range size and activity rates allows them to save energy during the cold season (Dunstone 1993). In Finland similar restricted movement of mink around suitable fishing places were observed (Niemimaa 1995).

For the period of mating season in spring, male mink considerably enlarged their home range while increased activity of both sexes was recorded. This substantial enlargement is interpreted concordantly as roaming in search of receptive females (Arnold and Fritzell 1987; Dunstone 1993; Gerell 1970; Niemimaa 1995). As the temperature increased, mink were no longer dependent on feeding hot spots, because during March most of the large fish ponds were stocked with carp. Furthermore, the availability of mammals and birds improved at this time, and consequently the shares of those prey categories increased in the spring diet of mink.

During summer months, activity rates of female mink continued to be high, because of increased energy requirements during the pup raising period (Ireland 1990). Both sexes used

comparatively large summer home ranges, while birds and mammals, which were available throughout the whole study area, made up the main part of prey.

In autumn – the time of yearly fish harvesting – again fish gained in importance in the mink diet. At this time fish is an easily catchable prey because of aggregation, moreover, a lot of exhausted fish can be found in the reed belts and at the banks of the ponds (Wichmann 2002). This was also the time when mink decreased their activity rates to the low winter level, and reduced their home range sizes.

Our results confirm the basic assumption that mink live in intra-sexual territoriality, with males having significantly larger home ranges than females (Dunstone 1993; Gerell 1970; Ireland 1990; Melero et al. 2008; Yamaguchi and Macdonald 2003). Levels of intra-sexual overlapping of home ranges were low, but throughout the year I observed high inter-sexual overlapping rates. This considerable overlap of male and female home ranges, leads to the necessity of resource partitioning between individuals of different sexes. In the literature several mechanisms have been noted that appear to reduce inter-sexual competition, e.g. spatial segregation between sexes (Yamaguchi et al. 2003; Zabala et al. 2007), or sexual differences in diet composition or prey size, regarding the sexual dimorphism in body size (Birks and Dunstone 1985; Ireland 1990; Thom et al. 2004).

No food niche partitioning between male and female mink was found. That means both sexes used the same prey categories and the composition of diet changed in a similar way during the course of the year. Additionally, there was no sexual segregation in range use. A males' territory often includes a part or whole of two or three female ranges and both sexes used the same feeding habitats. However, circadian time segregation between sexes was observed — all investigated females exhibited perennial diurnal behaviour, whereas males showed nocturnal or arrhythmic activity patterns. This daylight activity may allow females to enter a patch at a different time compared to males and consequently will increase their hunting successes. Gender-dependent activity patterns have also been proposed as a mechanism to reduce inter-sexual competition in some other studies on mink or polecat (Birks and Linn 1982; Harrington and Macdonald 2008; Marcelli et al. 2003; Thom et al. 2004).

The extent of intra- as well as inter-sexual overlap can be influenced by population density. In this study a relatively low but stable population density of about 0.6–0.7 resident mink per km^2 was assessed. In Europe, mink densities vary from below one to over ten individuals per

10 km of river or pond length (Bartoszewicz and Zalewski 2003; Brzeziński et al. 2010; Gerell 1970; Sidorovich et al. 1996; Smal 1991 a). Moreover, investigated mink used home ranges that were larger than in most other previous European studies (Brzeziński et al. 2010; Ireland 1990; Melero et al. 2008; Salo et al. 2010; Zabala et al. 2007). Assuming intra-sexual territoriality, estimated low density of mink and the above-average sizes of home ranges are closely related and interact with each other. So, it is assumed that high seasonal as well as sexual variation of home range size in the study area is possible because of the relatively low population density.

Probably, the spatially restricted and concentrated availability of food in winter months do not allow higher population density. Because of intrasexual intolerance, hot spots of prey such as hibernating ponds cannot be used by several individuals of the same sex. Therefore, the territorial system limits the number of mink that can live in this anthropogenic fishpond area over a longer time period. Furthermore, only a few transient mink were recorded, even during the mating season and in autumn, suggesting a low immigration rate.

This territorial system should be considered in the debate on the negative impact of the carnivore on their prey populations. A specific area is usually occupied by only two individuals (male and female), which prey on the available food resources. Their impact is therefore limited. However, some results, particularly the high proportion of birds in the summer diet, suggest a potential negative impact of invasive mink, especially on waterfowl. Breeding populations of coots, grebes, ducks and rails have decreased significantly at the nature reserve “Lewitz fish ponds” during the last 30 years (Zimmermann 2008). According to the author there are different reasons for this decline, such as changes in the usage of meadowlands and ponds but also a drastic increase in predation pressure. Often in cases where a decline of prey populations was recorded, several causes such as habitat change or strong predation pressure of the whole carnivore community were observed (Dunstone 1993). This seems to apply also to waterfowl at the study area (Borchert et al. 2012; Zimmermann 2008).

Nevertheless, Bonesi and Palazon (2007) reviewed that in several European countries, mink has a negative ecological impact through predation or competition, especially on ground nesting birds, rodents, amphibians and other mustelids. In contrast the overall economic impact of feral mink seems to be relatively small but can be significant in specific regions. In this regard Bonesi (2009) listed damage to free ranging chickens, reared game birds and

fisheries. However, in this study the high proportion of perch and roach and a moderate fraction of carp in mink diet indicate that the economic loss caused by mink predation is limited. In the “Lewitz fish ponds” concern of fish farmers as well as management measures are aimed rather at bird predators such as the heron (*Ardea cinerea*) or the great cormorant (*Phalacrocorax carbo*) than at mink (Zimmermann 2008).

The study area is strongly influenced by humans through management of fish ponds. In winter, most of the large ponds are drained off and the remaining fish (except carp) are concentrated in ice-free ditches, canals and water-filled fish-harvesting pools. At this time the younger carp are concentrated in small hibernating ponds, which in turn were drained during summer month (Wichmann 2002). Especially the resulting seasonal availability of habitat- and food resources affects feeding habits, activity patterns, space use and consequently density of the inhabiting mink population.

The results of this investigation confirm a high flexibility among American mink, which are able to occupy ecological niches in cultivated wetland habitats. Such a good adaptability to anthropogenically influenced ecosystems seems to be typical for many non-native invasive species (Essl and Rabitsch 2002).

9.2 Prevention and Management

Three main strategies for the control of IAS were distinguished, depending on their stage in the invasion process: 1) prevention 2) early detection 3) assessment and management of established species (Wittenberg and Cock 2001). Therefore, in the case of American mink in Europe all three strategies have to be pursued simultaneously.

Genovesi et al. (2009) noted that, considering the introduction of invasive mammal species since 1960, the pathway through fur farms is responsible for a relatively large proportion with 23 %. Concerning American mink, escapes from fur farms and additional "liberations" by animal rights activists during the last decades led to further spread of this invasive carnivore throughout Europe. Such as in Saxony-Anhalt – in 2007 about 15,000 farm mink individuals were illegally released, and it is assumed that approximately 2000 of them became established in the wild (Deutscher Jagdschutzverband e.V. 2011).

Consequently, a trade and keeping ban would be the most obvious tool to stop further introductions. Bonesi (2009) advises prevention by regulating the licenses of fur farms and improving fencing around farms to prevent further escapes. Additionally, a rapid response (e.g. quick capture efforts) after releases from mink farms is important (Bonesi and Palazon 2007).

Indeed, some European countries such as United Kingdom including Northern Ireland (since 2003) and Austria (since 2004) have banned fur farming. In Switzerland there are no fur farms because of very strict keeping regulations (Bonesi and Palazon 2007). In Italy improved keeping conditions will probably lead to the closure of Italian mink farms. Also in the Netherlands, the world's third largest producer of mink skins, legislation to phase out mink fur farming by 2024 was approved by the end of 2012 (http://www.respectforanimals.co.uk/facts-and-reports/fur-farming/53/).

In 2009 regulations on fur farming (Tierschutz-Nutztierhaltungsverordnung) in Germany were amended, to improve husbandry conditions. Some modifications will not come into effect until 2016. However, several mink farms have already been closed down. In March 2014 only eight of the former 32 mink farms in Germany were still in operation (Bonesi and Palazon 2007; http://www.tierschutzbund.de/fileadmin/user_upload/Downloads/Hintergrundinformationen/Artenschutz/Pelztierfarmen_2014.pdf). This European-wide trend to ban mink-

farms however is due to activities of animal welfare organisations, rather than to regulations preventing further introductions of this IAS. This is because the costs of management and control in Germany (estimated € 5 million/year, Reinhardt et al. 2003) as well as the costs of impacts (estimated € 4.2 million/year, Bonesi 2009) are contrasted with the profit of the mink farms (2011: production of 350,000 mink skins in Germany, European Fur Breeders' Association 2011).

According to the German Federal Nature Conservation Act, (Bundesnaturschutzgesetz § 40, 3) the competent authorities should take measures to prevent the further spread and to minimise the negative effects of already established invasive species. For successful implementation of this law it is important to establish an early detection and a monitoring system for the known invasive species. Furthermore, control and eradication measures should be prepared and applied if necessary. Finally, the success of these actions should be evaluated (Nehring et al. 2013).

The German Wildlife Information System (WILD), which includes the mink, is a first step in this process. However, the data about distribution came primarily from a survey of hunters and from analysing the hunting bag statistics (Grauer et al. 2008). Another problem is the fact that neither all owners of hunting districts nor all the federal states take part in that system. Furthermore, the time interval between surveys is long. These factors explain the fact that the data is fragmentary and partially out of date. Moreover, in most cases there is insufficient evidence.

Currently only in some federal states of Germany (Berlin, Brandenburg, Hessen, Mecklenburg-Vorpommern, Niedersachsen, Sachsen, Sachsen-Anhalt, Schleswig-Holstein, Thüringen) a hunting period for American mink is defined, but the species is not yet listed in the German federal hunting law (Bundesjagdgesetz) (Arnold et al. 2013). Therefore, an important step would be a uniform nationwide inclusion of mink in the hunting law. This would facilitate monitoring, because first evidence of mink in new areas would be obvious and the species would be recorded in the hunting statistics of all states. Because of their dependence on trapping efforts as well as trapping success, annual hunting bags give us only data about the presence of mink but not about its absence or population density and dynamic, respectively. Furthermore, hunters should be sensitized to invasive carnivores. They should be able to

identify the respective species and know which institution has to be informed in the case of finding evidence of their presence.

A systematic and profound monitoring of mink-presence should be based on the use of several methods. Indirect signs such as footprints or scats left along the river banks can be recorded relatively easily. A specific strategy for mink monitoring does not exist, but it could be implemented in the standard Eurasian otter surveys, which were conducted in most federal states of Germany within the scope of Fauna-Flora-Habitat (FFH)-monitoring (Melero et al. 2013; Reuther et al. 2000). In this procedure field signs such as tracks or scats were searched along a 600-m-transect at the riverbanks. Melero et al. (2013) found that this strategy was sufficiently adequate for surveying mink. The so called “floating mink rafts”, that quite clearly detect mink footprints, can also be used as a monitoring device (Harrington et al. 2008; Reynolds et al. 2004). However, in areas with polecat presence even for skilled surveyors it is difficult to distinguish between field signs of mink and polecat (Harrington et al. 2008; Harrington et al. 2010). Hence, for areas with similar sympatric species (especially European mink or polecat), in accordance with Harrington et al. (2010) I recommend additional methods such as Deoxyribonucleic Acid (DNA)-analysis of scats (cost-intensive) or camera traps, to verify species identification. The use of data from other monitoring-projects (e.g. FFH-monitoring for polecat) could be a first step. After that, it makes sense to conduct active-monitoring in the areas with no data. Besides the monitoring of existing populations (spread, population trend), the influence of mink on prey populations as well as on potential competitors should be monitored. Monitoring can also indicate the level of success of the management measures.

Finally, management actions derived from the monitoring results should be adapted to local conditions. As Bonesi and Palazon (2007) found, eradication campaigns on small islands away from the mainland are most effective on a long-term scale, because recolonisation from neighbouring regions is unlikely. There are several studies about local mink eradication, also investigating positive effects on prey populations (e.g. Harrington et al. 2009; Moore et al. 2003; Nordström and Korpimäki 2004). Large-scale mink eradication on the mainland seems to be almost impossible because of its enormous costs and manpower requirements. But Bryce et al. (2011) showed that a community based approach – with volunteer participation - could be a way to achieve mink eradication on mainland Scotland. Besides local control or

eradication, several other actions for mitigating the impact of mink, such as habitat restoration, promotion of native mink competitors (e.g. the Eurasian otter) or management of prey species were recommended (Bonesi and Palazon 2007; Macdonald and Harrington 2003).

In Germany feral mink is already widespread, at least in the eastern and northern regions (Deutscher Jagdschutzverband e.V. 2011). Therefore, nationwide eradication is not feasible, but management should focus on actions that minimise the negative impact on a local scale. On the one hand, effective mink control can be an option, for instance in environmentally sensitive areas, such as bird sanctuaries or in regions which have been newly colonised. In other circumstances mink exclusion devices (mink-proof fencing or repellents) are a practicable tool, e.g. in fish ponds or at small artificial bird islands.

Mink trapping:

Most mink-trapping campaigns have been conducted during the cold season. Therefore, for trapping design, it is important to take into account the smaller winter home ranges and spatial concentration of mink activity around food hot spots. To ensure the capture of all resident (breeding) females, it is necessary to place a trap at each area with increased mink activity. Such places could be detected by snow-tracking, mink rafts (Reynolds et al. 2004) or camera traps. If it is not possible to identify such places, this study supports the recommendation of Melero et al. (2008) to place traps at regular locations every 150–200 m along the water banks. Traps should be placed preferably in dense vegetation (important for coverage and food), near potential den sites (natural and artificial) and at junctions of water bodies. I recommend two-door entrance box traps of wire mash or wood. Different baits such as fish, meat, eggs or commercial “lure” can be used, but I gained the best trapping results with the odour of another mink. With the mink rafts developed by Reynolds et al. (2004) an effective and above all selective trapping of mink was possible (Stier et al. in prep).

Mink control can benefit from knowledge of the typical space use pattern of the species. For example, trapping male mink is very effective during the mating season because individuals traverse large regions and therefore more frequently encounter traps in unknown areas.

In a few mink control projects, the use of dogs was described. Moore et al. (2003) used the dogs for searching mink dens and then placed the traps in close proximity to the den entrances. This strategy improved the trapping results especially in early summer, when mink trapping is difficult as well as in low density populations (to trap also the last individuals). In Iceland dogs were trained for mink hunting

by the Wildlife Management Institute. The dogs are able to detect active mink dens as well as to attack and kill the mink (Hersteinsson 2000).

Mink exclusion:

Another strategy in mink management can be exclusion devices, for instance mink-proof fencing or repellents (Bonesi 2009; Macdonald and Harrington 2003). To protect sensitive areas such as breeding bird islands or fish farms, fences designed to exclude or deter predators could be a cost-effective strategy (West et al. 2007; Smal 1991 b). Smal (1991 b) recommends a wire mesh fence with mesh less than 4.5 cm in diameter and a wide metal sheet (60 cm) around the top, to prevent climbing over. Additionally, the fence should be buried, to avoid mink burrowing in. Electric fences can also be suitable; four strands with a distance of about 10 cm should keep out the mink and other terrestrial predators (Smal 1991 b). However, the immense effort required for installation and maintenance restrict the use of electric fences to small areas (Langgemach and Bellebaum 2005).

In conclusion a good management strategy should include monitoring and control of the mink population. Moreover, it should be focused on management objectives as well as on local circumstances. Recently the European Parliament has improved the legal framework by publishing a Regulation (No 1143/2014) on the prevention and management of the introduction and spread of invasive non-native species. It entered into force on 1st January 2015. The main objectives of this regulation are the prevention, minimization and mitigation of the adverse impacts on biodiversity caused by the introduction and spread of invasive non-native species within the European Union. Cross-border cooperation is recommended, and three types of interventions are required: prevention, early detection and rapid eradication, and management. IAS which are of particular concern to the European Union will be drawn up in a list. This “List of IAS of Union concern” has to be developed by the Member States using risk assessments and scientific evidence, and should be completed in January 2016 (http://ec.europa.eu/environment/nature/invasivealien/index_en.htm; Beninde et al. 2014,). With the implementation of this new regulation throughout the European Union, the basic requirements for an effective and consistent management of invasive species, such as American mink, would be met.

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Tharandt, Dezember 2015

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